LED Roadway Lighting: Palo Alto Residential and Commercial Streets

In 2007, the City Council of Palo Alto, California, adopted a Climate Protection Plan (CPP) that set a goal of reducing greenhouse gas (GHG) emissions by 15 percent of 2005 levels, or 119,140 metric tons of carbon dioxide (CO_2), by 2020.

Source: Google Earth

Three luminaires, each having 20 LEDs, were installed on separate poles at this site.

A short-term action item from the CPP was to evaluate the cost-effectiveness of light-emitting diode (LED) technology for streetlights. LED technology could reduce GHG emissions and decrease operational costs by saving energy and reducing maintenance. In support of this action item, the City of Palo Alto requested that Pacific Northwest National Laboratory (PNNL), through the U.S. Department of Energy (DOE) Solid-State Lighting GATEWAY Demonstration Program, assist them with selecting luminaires, conducting field measurements of the lighting, and assessing the performance of the baseline and test luminaires.

Project Description

The demonstration project team consisted of staff from PNNL and the City of Palo Alto. The team tested both LED and induction streetlights, since both technologies could save energy and reduce maintenance costs. A total of seven LED and three induction streetlight luminaires were installed on three residential streets in Palo Alto, replacing 70W (rated lamp power) high-pressure sodium (HPS) luminaires. On Street 1, 20-LED luminaires were installed to match the *minimum* illuminance of the incumbent 70W HPS system. On Street 2, 30-LED luminaires were installed to match the *average* illuminance of that system. On Street 3, the induction system was installed and was similarly sized to match the *average* illuminance of the HPS system. Light and electrical power measurements were taken both before and after the installation of the LED and induction luminaires. Feedback on the replacement lights was obtained from three interested parties: the local community, the Palo Alto Police Department, and the city's Utilities Department operations staff who currently maintain the HPS streetlights.

The City of Palo Alto does not have a specification for streetlighting. Therefore, to evaluate system performance against a recognized standard (consistent with similar studies), the three systems were compared to IES RP-8, *Roadway Lighting*. IES RP-8 recommends an average illuminance of 0.4 footcandles (fc) and an average/minimum uniformity ratio of 6:1 for these types of roadways. As shown in Table 1 on Page 2, none of the evaluated systems met this level of uniformity. The average illuminance values for the HPS systems vary widely in the table, even though the same luminaires are used on all three streets with roughly the same spacing. This indicates that other real-world elements (e.g., trees) are affecting the lighting distribution. These elements caused an especially low minimum value on Street 2 for the 30-LED system, with a high average/minimum ratio. Coefficient of variation (CV) is an alternative uniformity metric that reduces the effect of extreme values occurring in only one or a few locations and thus gives a better indication of how much the illumination varies across the entire area (lower values indicate less variation). The CV values in Table 1 indicate that on Street 2, the LED is slightly more uniform overall than the HPS, despite the extremely low minimum value measured within that space.

Palo Alto considers the 30-LED luminaire a technical success because it uses less energy than the incumbent HPS system while providing matching or better illumination. Of the three systems (induction, 20-LED, and 30-LED), the

30-LED system saved the most energy (44% reduction compared to the baseline HPS) while maintaining suitable light levels. Factors contributing to the energy savings include power supply and optical inefficiencies of conventional cobra-head types of fixtures.

Overall, community feedback obtained during the evaluation revealed a marked subjective preference for LED over both the induction and the HPS lights. Increased color perception and visibility were given as key advantages of LED luminaires. This preference did not extend to all LED characteristics, however; two common concerns related to LED lights were excessive glare and the perceived blue/cold color of the LED light output.

Economic Performance

The economic analysis reported in Table 2 demonstrates that, despite the energy savings, converting existing streetlights in Palo Alto from HPS to LED or induction is not yet economically favorable, with simple payback periods ranging between 9 and 17 years. For new construction, the corresponding payback periods are slightly shorter, ranging from 7 to 16 years. The net present values shown for each scenario in the table were calculated using a relatively low discount rate of 4.5 percent.

For the City of Palo Alto, replacing all existing 70W HPS luminaires with the preferred 30-LED luminaires would have an average projected payback period of 12 years at an energy cost of $0.08/kilowatt-hour.

Table 1: Illuminance and Power Summary Comparison for the Residential Streets

	Street 1		Street 2		Street 3	
Light Source	HPS	20-LED	HPS	30-LED	HPS	Induction
Average	0.44 fc	0.24 fc	0.36 fc	0.43 fc	0.27 fc	0.23 fc
Minimum	0.03 fc	0.02 fc	0.02 fc	0.01 fc	0.01 fc	0.01 fc
Maximum	2.64 fc	1.02 fc	1.68 fc	1.47 fc	1.34 fc	1.52 fc
Avg/Min	15:1	12:1	18:1	43:1	27:1	23:1
Std. Dev	0.54 fc	0.26 fc	0.38 fc	0.44 fc	0.24 fc	0.29 fc
CV	1.22	1.08	1.05	1.04	0.90	1.23
Total Power Draw*	96W	42W	96W	54W	96W	90W
Energy Savings	N/A	56%	N/A	44%	N/A	6%

*Power measurements for both the baseline and new luminaires were taken at the same point in the circuit. Measurements were taken for multiple luminaires, and the average values are presented.

Table 2: Payback Period and Net Present Value of LED and Induction Systems (Dec. 2009)

	Retrofit		New Construction	
	Simple Payback (years)	Net Present Value	Simple Payback (years)	Net Present Value
20-LED Luminaire	9	$122	7	$201
30-LED Luminaire	12	—$15	10	$64
Induction Luminaire	17+	—$173	16	—$105

Conclusions

Although all of the tested alternatives saved energy, commodity-grade pricing for the incumbent HPS and the low cost of electricity in this location make it difficult to justify the investment based solely on the valuation of benefits available at the time the study was completed. Expanded recognition (or monetization) of benefits, such as the broad spectrum output that increases color recognition or new control capabilities that bring additional value, will likely be necessary to justify upgrades to the lighting system in locations where such economic conditions apply.

DOE GATEWAY Demonstrations utilize a variety of commercial and residential lighting applications to identify new SSL products that achieve three goals:

- Save energy relative to the incumbent technology;
- Match or better the existing illumination and visibility produced by the incumbent technology;
- Offer economic value to users.

This Report Brief provides a summary of a full GATEWAY Demonstration report; both are available online at www.ssl.energy.gov/gatewaydemos.html.

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